

Voxel Advanced Digital-manufacturing for Earth & Regolith in Space Project

Center Innovation Fund: KSC CIF Program | Space Technology Mission Directorate (STMD)



ABSTRACT

A voxel is a discrete three-dimensional (3D) element of material that is used to construct a larger 3D object. It is the 3D equivalent of a pixel. This project will conceptualize and study various approaches in order to develop a proof of concept 3D printing device that utilizes regolith as the material of the voxels. The goal is to develop a digital printer head capable of placing discrete self-aligning voxels in additive layers in order to fabricate small parts that can be given structural integrity through a post-printing sintering or other binding process. The quicker speeds possible with the voxel 3D printing approach along with the utilization of regolith material as the substrate will advance the use of this technology to applications for In-Situ Resource Utilization (ISRU), which is key to reducing logistics from Earth to Space, thus making long-duration human exploration missions to other celestial bodies more possible.

ANTICIPATED BENEFITS

To NASA funded missions:

This project intends to show that the previous modeling of Voxels done by others **can be rapidly translated** into a physical instantiation of the three dimensional object that was virtually modeled using software methods only. In addition, indigenous materials found on planetary surfaces and asteroids will be used to show how this technique could be used **to fabricate objects in space**. Such a capability is the key to **reducing logistics from Earth to Space** and will provide substantial **mass launch savings** as well as **operational flexibility and robustness**.

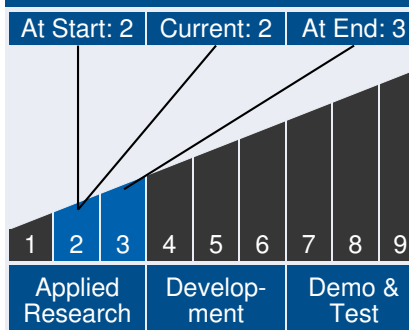
On Earth, this fabrication method could take the **3D Additive Manufacturing revolution to the next level**, providing unprecedented **speed and accuracy** for digital metallic parts with high structural integrity and good materials properties.



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Technology Maturity



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On Earth, this fabrication method could take the **3D Additive Manufacturing revolution to the next level**, providing unprecedented **speed and accuracy** for digital metallic parts with high structural integrity and good materials properties.

To other government agencies:

This project intends to show that the previous modeling of Voxels done by others **can be rapidly translated** into a physical instantiation of the three dimensional object that was virtually modeled using software methods only. This fabrication method could take the **3D Additive Manufacturing revolution to the next level**, providing unprecedented **speed and accuracy** for digital metallic parts with high structural integrity and good materials properties.

To the commercial space industry:

This project intends to show that the previous modeling of Voxels done by others can be rapidly translated into a physical instantiation of the three dimensional object that was virtually modeled using software methods only. In addition, indigenous materials found on planetary surfaces and asteroids will be used to show how this technique could be used to fabricate objects in space. Such a capability is the key to reducing logistics from Earth to Space and will provide substantial mass launch savings

Management Team

Project Manager:

- Nancy Zeitlin

Principal Investigator:

- Robert Mueller

Technology Areas

Primary Technology Area:

Human Exploration Destination Systems (TA 7)

└ Materials, Structures, Mechanical Systems & Manufacturing (TA 12)

Secondary Technology Area:

Robotics, Tele-Robotics & Autonomous Systems (TA 4)

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To the nation:

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DETAILED DESCRIPTION

A **voxel** is a discrete **three-dimensional (3D)** element of material that is used to construct a larger 3D object. **It is the 3D equivalent of a pixel.**

“The **transition from analog to digital** has revolutionized many fields over the past century – most notably computation and communication – and can be used to similarly revolutionize additive manufacturing technology. **Digital materials are composed of many discrete, self-aligning voxels placed in a massively parallel layer deposition process**, as opposed to continuous (analog) deposition techniques. Digital principles allow for perfect replication and zero noise despite using a noisy and inaccurate substrate. The paradigm of digital printing with prefabricated voxels enables parts composed of multiple materials with mutually incompatible processing characteristics and specific functionality to be effortlessly combined in a **single freeform fabrication process**”, (Hiller & Lipson, 2013). This allows higher speeds of fabrication than 3d printing allows.

A characteristic **proof of concept device** using regolith derived materials will be researched, conceptualized, designed, fabricated & tested in a lab environment to raise the TRL to 3.

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A comprehensive literature survey will ensure that this team leverages from the state of the art research previously performed at universities such as Cornell U (Hiller et al) .

Digital materials, which are composed of many **self aligned fundamental building discrete materials known as voxels** , offer advantages over conventional analog materials used in all current manufacturing processes. **Regolith particles and voxels that could be derived from regolith** will be investigated for a parallel layer deposition process using electrostatics or magnetic forces to digitally emplace arrays in successive layers which will then be **sintered to form a net shape solid**. A digital print head will be developed that is capable of placing **discrete self-aligning voxels in additive layers** to precisely build parts using voxel spheres or other regular shaped solids. **Small parts will be fabricated as a demonstration** in a bench top proof-of-concept print head device. Sintering or other binding methods will be used in **a post processing step to make a solid part** with structural integrity.

“Although voxels are routinely used as a data structure in computer graphics, (Chandru et al., 1995) and even to prepare models for conventional freeform fabrication (Lin et al., 2007), here we refer to them as **physical bits in digital matter**.” (Hiller, 2013)

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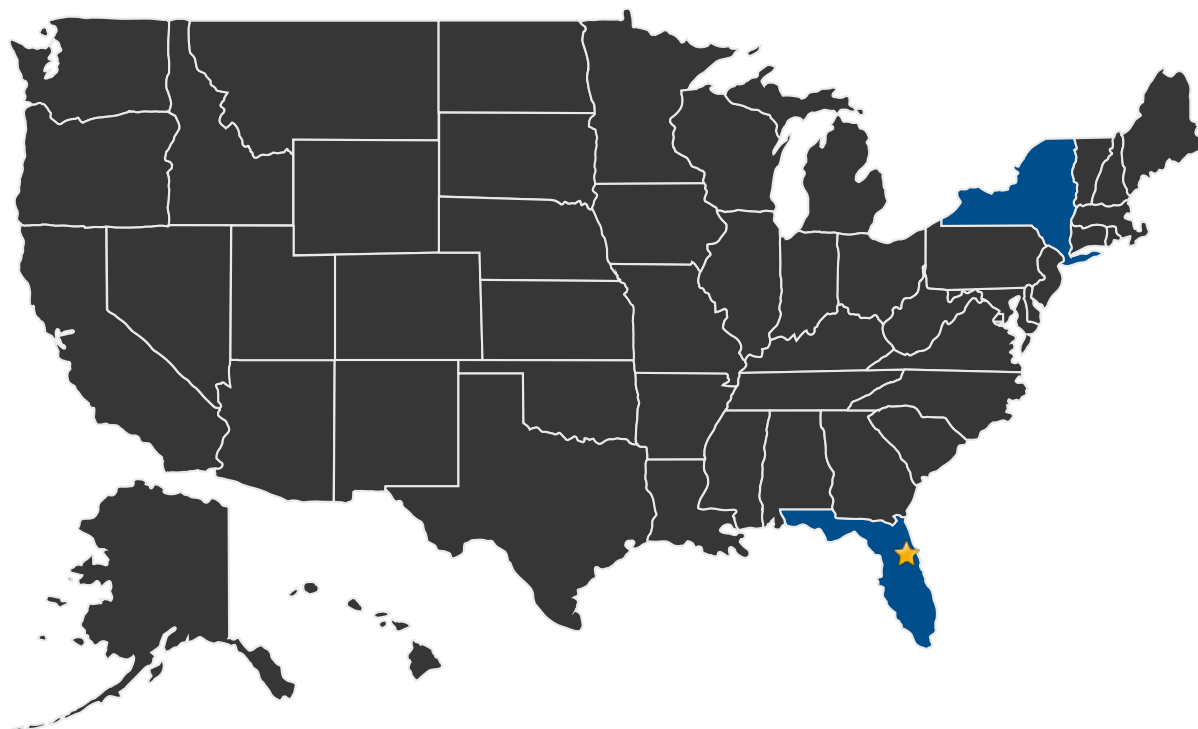
Active Project (2015 - 2016)

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U.S. LOCATIONS WORKING ON THIS PROJECT



■ U.S. States With Work

★ **Lead Center:**
Kennedy Space Center

Contributing Partners:

- Columbia University

TechPort

For more information visit techport.nasa.gov

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Some NASA technology projects are smaller (for example SBIR/STTR, NIAC and Center Innovation Fund), and will have less content than other, larger projects. Newly created projects may not yet have detailed project information.

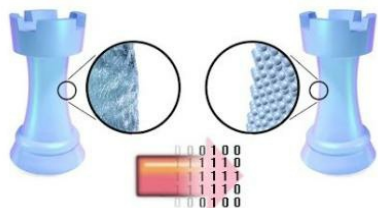
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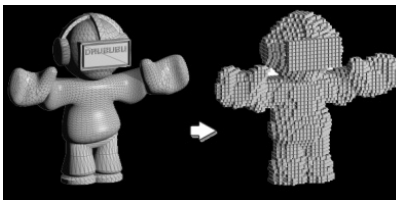
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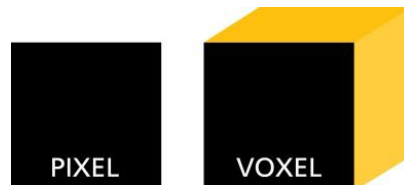
IMAGE GALLERY



Digital coding for voxel manufacturing



A 3D object converted into voxels



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DETAILS FOR TECHNOLOGY 1

Technology Title

Voxel Advanced Digital-manufacturing for Earth & Regolith in Space

Technology Description

This technology is categorized as a hardware system for other applications

"Digital materials are composed of many discrete, self-aligning voxels placed in a massively parallel layer deposition process, as opposed to continuous (analog) deposition techniques. Digital principles allow for perfect replication and zero noise despite using a noisy and inaccurate substrate. The paradigm of digital printing with prefabricated voxels enables parts composed of multiple materials with mutually incompatible processing characteristics and specific functionality to be effortlessly combined in a **single freeform fabrication process**", (Hiller & Lipson, 2013).

Capabilities Provided

This project intends to show that the previous modeling of Voxels done by others **can be rapidly translated** into a physical instantiation of the three dimensional object that was virtually modeled using software methods only. In addition, indigenous materials found on planetary surfaces and asteroids will be used to show how this technique could be used **to fabricate objects in space**. Such a capability is the key to **reducing logistics from Earth to Space** and will provide substantial **mass launch savings** as well as **operational flexibility and robustness**.

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Potential Applications

Revolutionizing 3D additive manufacturing.

The quicker speeds possible with the voxel 3D printing approach along with the utilization of regolith derived material (such as metals or silicates) as the substrate will advance the use of this technology to applications for In-Situ Resource Utilization (ISRU), which is key to reducing logistics from Earth to Space, thus making long-duration human exploration missions to other celestial bodies more possible.

Performance Metrics

Metric	Unit	Quantity
Voxel Size	5 mm	1
Part size	1m ³	1
Improve fabrication speed compared to Fused Deposition Manufacturing today	hours	48